Surface Soil Moisture Downscaling Using Microwave Data. Application and Comparison

McMaster Water Resources and Hydrologic Modeling Lab

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INTRODUCTION

Microwave remote sensing has become a useful tool for near-surface soil moisture estimation based on the contrast in dielectric properties between dry soil and water derived from backscatter data and microwave emissions. In hydrologic studies, soil moisture is a critical component as it control the partitioning between infiltration and run-off and in partitioning the incoming radiation between latent and sensible heat fluxes [1]- [4]. The hydrological and climatological process influenced by soil moisture can impact many environmental phenomena from extreme events like droughts and flooding to state patterns such as ecological distribution of homogenous vegetation zones [2], [5].

Satellite-based microwave remote sensing is the most promising technique for providing key elements of the near-surface soil moisture [3], [6]. However, the spatio-temporal resolution of the recent microwave remote sensing data is a drawback for near-surface soil moisture retrieval. Their use in hydrological and agricultural predictions is limited because of the discrepancy in scale between the satellite products a (> 25 km) and that of hydrological processes (< 1 km) [1]. In the case of flood prediction and flood forecasting application, this research focuses on downscaling soil moisture, while also improving the hydrological simulation accurately.

An adapted method of disaggregation [6] and ensemble Kalman filter (EnKF) [7], [8] will be applied for soil moisture downscaling on a field site near Kenaston area, Saskatchewan. The Moderate Resolution Imaging Spectroradiometer (MODIS), RADARSAT-2, Soil Moisture Active Passive (SMAP) and Soil Moisture and Ocean Salinity (SMOS) soil moisture data will be used in this research.

KENASTON AREA

The field site [51.14N–51.70N; 105.67W–106.79W] is located south of Saskatoon near Kenaston, Saskatchewan covers an area of 33 km x 71 km (Fig.1). The site benefits from two existing soil moisture measurement networks managed by Environment Canada and the University of Guelph. The study area was designed to avoid the irrigated fields along Diefenbaker Lake and South Saskatchewan River to the west and south, by hummocky uplands to the northeast and by Diefenbaker Lake and forested areas to the south [9].

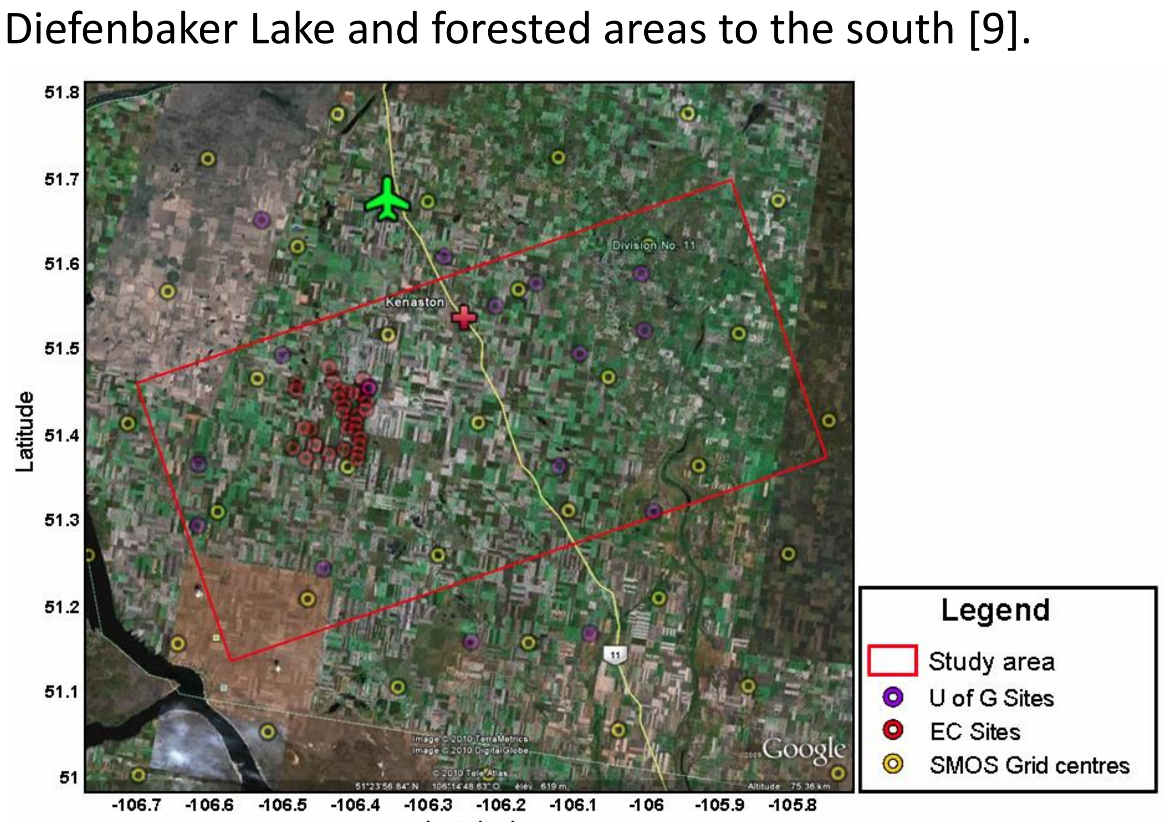

Figure 1. Location of Kenaston site [9]

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DATA

A. Satellite images:

Time series (2015, 2016) of different microwave data will be used:

1. SMAP level 2 soil moisture data product, L-Band: is soil moisture derived from the radiometer brightness temperature measurements and is posted at 36 km.

SMAP soil moisture calibrated data: all the sites were calibrated using a dry-down method [10] and general calibration equation [11].

2. SMOS level 2 soil moisture data product: are retrieved on the 15 km ISEA 4H9 (Icosahedral Snyder Equal Area) discrete global grid (DGG) but reprehensive of nonlinearly weighted ~ 43 km SMOS sampling resolution.
3. MODIS: level 3 global 1 km grid.
4. RADARSAT-2 C-Band: Standard mode, 100 m resolution

B. Kenaston soil moisture mesonet :

The high-density network consists of 37 soil moisture station of Environment Canada and of University of Guelph (Fig. 2).

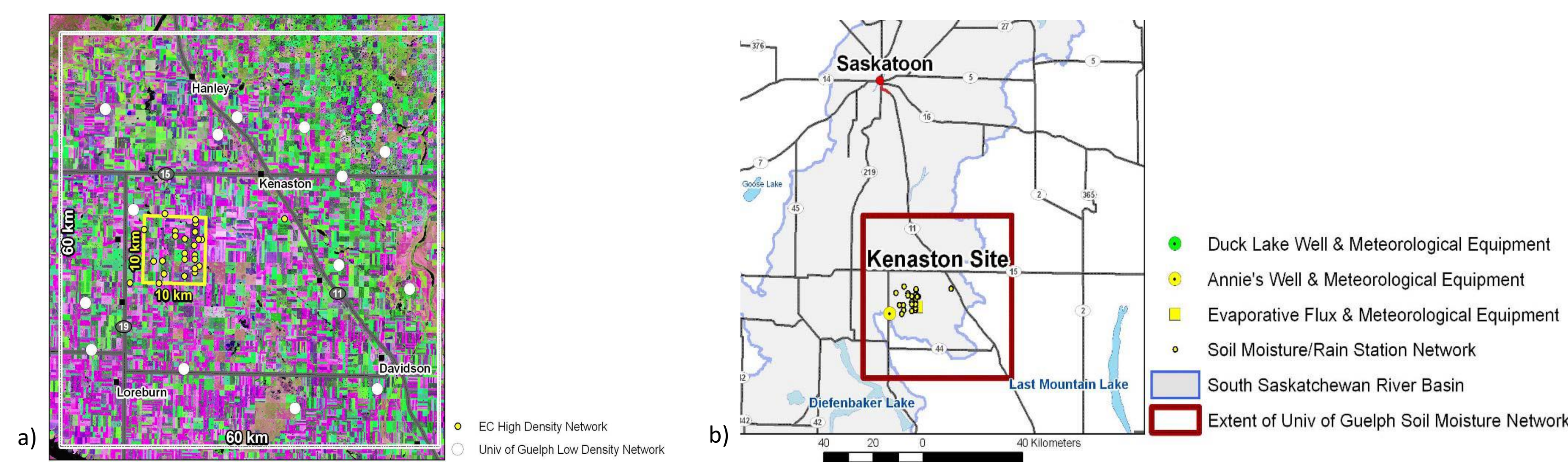

Figure 2. a) The nested study area superimposed on a false colour Landsat image from 1999 (mid IR, near IR, red);
b) The Kenaston soil moisture mesonet (EC and U of G) near Saskatoon, SK [9]

OBJECTIVES

The main objective of this research is downscale soil moisture from SMOS/SMAP at a resolution of 40 km to a resolution of approximately 1 km to be assimilated into a hydrological model to improve flood forecasting.

A comparison of the different downscaling methods in order to recognize the limit/efficiency of each method in the context of the studied area and its capability when apply to other area.

METHODOLOGY

1. Disaggregation, DisPATCh method [6]:

$$\mathrm{SM}_{1\ \mathrm{km}} = \mathrm{SM}_{\mathrm{SMOS}} + \frac{\partial \mathrm{SM}_{\mathrm{mod}}}{\partial \mathrm{SEE}} \times \left(\mathrm{SEE}_{\mathrm{MODIS,1\ km}} - \langle \mathrm{SEE}_{\mathrm{MODIS,1\ km}} \rangle_{40\ \mathrm{km}}\right) \qquad \text{(Eq. 1)}$$

SM_{SMOS}: the SMOS soil moisture,

SEE_{MODIS} :the MODIS-derived Soil Evaporative Efficiency (ratio of actual to potential evaporation),

$\langle SEE_{MODIS} \rangle_{40\ km}$ its average within a SMOS pixel and

$\partial SM_{mod}/\partial SEE$ the partial derivative evaluated at SMOS scale of soil moisture with respect to soil evaporative efficiency.

The disaggregation procedure decouples the soil evaporation from the 0-5 cm soil layer and the vegetation transpiration from root-zone soil layer by separating MODIS surface temperature into its soil and vegetation components. MODIS derived soil temperature is then used to estimate soil evaporative efficiency (SEE). SEE_{MODIS} us used as a proxy for surface SM within the SMOS pixel [6]. Equation 1 shows the link between surface soil moisture and SEE at different scales.

First, the method will be applied to the study area using MODIS data, then RADARSAT-2 data for downscaling.

With the results obtained, the 1st paper will be submitted.

Time scheduled: data processing and result analysis from Sept. 2016 to Jan. 2017; Paper writing and submission: from Feb. to Mar. 2017.

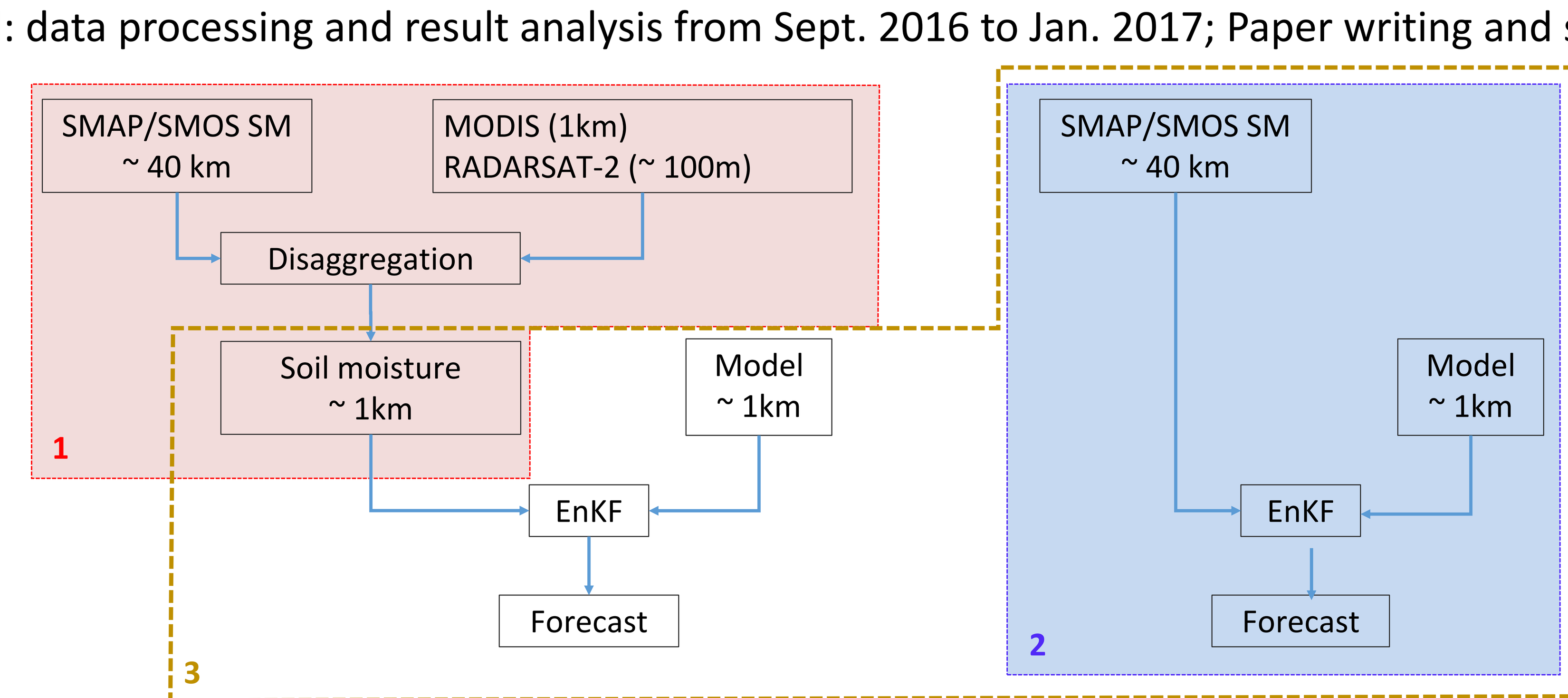

Figure 3. Methodology flowchart

2. Data assimilation: Ensemble Kalman Filter (EnKF) [7],[8]

The soil moisture data assimilation will be carried using EnKF, a Monte-Carlo variant of the Kalman filter. The EnKF is flexible in its treatment of errors in model dynamics and parameters. It is also very suitable for modestly nonlinear problems and has become a popular choice for land data assimilation [8]. A model of 1 km will be setup for this system.

3. Comparison: This performance focuses on comparison of the efficiency between two hourly time series dataset SMAP and SMOS.

In order to do this comparison, the result obtained from 1 (Fig.3) will be integrated into the model 1 km which was setup in 2 (Fig.3) using the same EnKF.

The results of the 2nd and 3rd applications will be the content for the 2nd paper.

Time scheduled : Setup, testing model and result analysis: from Apr. to Aug. 2017; Paper writing and submission: from Sept. to Oct. 2017.

ACKNOWLEDGEMENT

Natural Sciences and Engineering Research Council of Canada (NSERC) for funding support.

Professor Dr. Aaron Berg and Dr. Tracy Rowlandson of University of Guelph in supporting of the data and reference documents during this research.